AMENDMENTS TO THE SPECIFICATION:

Page 1, please add the following new paragraphs before paragraph [0001]:

[0000.2] CROSS-REFERENCE TO RELATED APPLICATIONS

[0000.4] This application is a 35 USC 371 application of PCT/DE 2004/000565 filed on March 19, 2004.

[0000.6] BACKGROUND OF THE INVENTION

Please replace paragraph [0001] with the following amended paragraph:

[0001] ~~Prior Art~~ **Field of the Invention**

Please replace paragraph [0002] with the following amended paragraph:

[0002] The invention relates to an **improved** actuator unit comprised of a piezoelectric actuator. ~~Actuator units of this kind are use among other things in fuel injection systems and in particular in fuel injection valves since the switching times of such actuator units are very short. The short switching times permit a more exact metering of the injected fuel quantity and permit an improved shape of the injection curve over time. In connection with the present invention, the generic term "fuel injection valve" is understood to mean all types of fuel injection valve, for example, the injectors for common rail injection systems or injection nozzles of conventional fuel injection systems. A fuel injection valve with a piezoelectric actuator is triggered by applying an electric voltage to the piezoelectric actuator; this causes a rapid expansion of the piezoelectric actuator due to known physical effects of piezoelectric ceramic and causes a valve-closure member to lift away from a valve seat. The piezoelectric actuator has a certain mass that is accelerated in the course of this. If the voltage applied to the actuator is reduced, this causes the actuator to contract. As a function of the triggering~~

~~speed, the inertia of the previously accelerated mass of the actuator generates damaging tensile forces in the piezoelectric actuator, in particular causing fractures in the soldered connections between the individual layers of the piezoelectric actuator. In order to prevent this kind of damage, it has become common practice to use a cylindrical hollow body in the form of a spring to prestress the piezoelectric actuator in the axial direction. A device of this kind is known, for example, from WO 00/08353 (Siemens). This hollow body is bent from a flat metal sheet and welded at the first joint thus produced. The first joint extends parallel to the longitudinal axis of the hollow body.~~

Please add the following <u>new</u> paragraph after paragraph [0002]:

[0002.2] Description of the Prior Art

Please add the following <u>new</u> paragraph after paragraph [0002.2]:

[0002.4] Actuator units of the type with which this invention is concerned are use among other things in fuel injection systems and in particular in fuel injection valves since the switching times of such actuator units are very short. The short switching times permit a more exact metering of the injected fuel quantity and permit an improved shape of the injection curve over time. In connection with the present invention, the generic term "fuel injection valve" is understood to mean all types of fuel injection values, for example, the injectors for common rail injection systems or injection nozzles of conventional fuel injection systems. A fuel injection valve with a piezoelectric actuator is triggered by applying an electric voltage to the piezoelectric actuator; this causes a rapid expansion of the piezoelectric actuator due to known physical effects of piezoelectric ceramic and causes a valve-closure member to lift away from a valve seat. The piezoelectric actuator has a certain mass that is

accelerated in the course of this. If the voltage applied to the actuator is reduced, this causes the actuator to contract. As a function of the triggering speed, the inertia of the previously accelerated mass of the actuator generates damaging tensile forces in the piezoelectric actuator, in particular causing fractures in the soldered connections between the individual layers of the piezoelectric actuator. In order to prevent this kind of damage, it has become common practice to use a cylindrical hollow body in the form of a spring to prestress the piezoelectric actuator in the axial direction. A device of this kind is known, for example, from WO 00/08353 (Siemens). This hollow body is bent from a flat metal sheet and welded at the first joint thus produced. The first joint extends parallel to the longitudinal axis of the hollow body.

Page 2, please replace paragraph [0004] with the following amended paragraph:

[0004] ~~Advantages of the Invention~~

SUMMARY AND ADVANTAGES OF THE INVENTION

Please replace paragraph [0005] with the following amended paragraph:

[0005] The actuator unit according to the present invention has a hollow body and a piezoelectric actuator. The hollow body is elastically embodied, prestresses the actuator, is provided with **apertures** recesses, has a joint extending parallel to the longitudinal axis, has a bridge piece between each pair of recesses, and has a first end and a second end. According to the present invention, the recesses adjacent to the joint are smaller than the rest of the recesses.

Please replace paragraph [0006] with the following amended paragraph:

[0006] Alternatively, it is also possible according to the present invention for the bridge piece between a recess adjacent to the joint and [[a]] **another** recess adjacent to ~~said~~ **that** recess to be wider than the bridge pieces between the rest of the recesses.

Page 3, please replace paragraph [0008] with the following amended paragraph:

[0008] The embodiments according to the present invention, which can be comprised in embodying the recesses adjacent to the joint as smaller than the rest of the recesses of the blank and/or embodying the bridge pieces in the region of the joint as wider than in the rest of the blank, serve to intentionally reinforce the hollow body in the regions in the immediate vicinity of the joint so as to compensate for the reduction in the spring rate in the region of the joint. It is therefore possible to achieve a spring rate of the hollow body that is constant and/or rotationally symmetrical over its entire circumference so that the piezoelectric actuator that the spring force of the hollow body acts on is loaded with forces exclusively the axial direction and not with lateral forces or bending moments. This can significantly extend the service life of actuator units equipped with a hollow body according to the present invention. It has turned out to be advantageous if the ratio of the width of a bridge piece between a recess adjacent to the joint **and a recess adjacent to that recess** to the width of the remaining bridge pieces of the blank has a value between 1.3 and 1.9, preferably 1.6. This means that the bridge pieces in the immediate vicinity of the joint are wider, for example by a factor of 1.6, than the rest of the bridge pieces of the blank.

Page 5, please replace paragraph [0015] with the following amended paragraph:

[0015] In a favorable embodiment form, the radius R_1 of a recess adjacent to the joint is smaller by a factor of 0.867 than the radius R_1 of the rest of the recesses. In addition, the second radius R_2 of a recess adjacent to the joint is larger by a factor of 1.317 than the radius R_2 of the rest of the recesses of the blank. Moreover, the length of a recess adjacent to the joint is shorter by a factor of 0.984 than the length of the rest of the recesses. The width of the bridge piece at the joint is expressed by the equation $b > a/2$; in particular $b = 1.4 \cdot a/2$. A detailed description of the related values, in particular the values "a" and "b," is given below in conjunction with the ~~figures~~ **drawings**.

Please replace paragraph [0016] with the following amended paragraph:

[0016] In another exemplary embodiment, it has also turned out to be advantageous if the recesses adjacent to the joint have the following dimensions:

R_1 = 0.35 mm – 0.43 mm, in particular 0.39 mm

R_2 = 4.0 mm – 8.9 mm, in particular 5.0 mm [[or]] **to** 7.9 mm

L = 3.5 mm – 4.5 mm, in particular 4.0 mm.

Page 7, please replace paragraph [0022] with the following amended paragraph:

[0022] According to the present invention, the hollow body can also have a region that is not perforated by recesses at its first end and/or at its second end. As a result of this, the spring force transmitted by the hollow body to a cover plate or another component of the injector is comparatively[[,]] **uniform** since the hollow body is intentionally reinforced in the region of its ends. This translates into a reduction in the maxima of the spring force over the

circumference of the hollow body and further alleviates the problem of lateral forces introduced into the piezoelectric actuator by the hollow body.

Page 8, please delete paragraph [0027].

Page 9, please replace paragraph [0028] with the following amended paragraph:

[0028] ~~Drawings~~ **BRIEF DESCRIPTION OF THE DRAWINGS**

Please add the following new paragraph after paragraph [0028]:

[0028.5] The foregoing and other features and advantages will become apparent from the description herein below, taken with the drawings, in which:

Page 10, please replace paragraph [0042] with the following amended paragraph:

[0042] ~~Description of the Exemplary Embodiments~~

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Page 11, please replace paragraph [0045] with the following amended paragraph:

[0045] The hollow body 4 is preferably made of spring steel. The hollow body 4 is provided with a multitude of **apertures,** recesses 7 in order to be able to set a desired spring rate with a predetermined wall thickness "s." For the sake of clarity, not all of the recesses in Fig. 1 are provided with reference numerals. Since the multitude of recesses 7 can best be produced by means of punching, the hollow body 4 is as a rule comprised of sheet metal. First, a blank with the recesses 7 is stamped out of the metal sheet. Then, the blank is bent until it has a

circular cross section, for example, or a cross section in the shape of a regular polygon. This produces a first joint where the two ends of the bent blank meet each other (not shown in Fig. 1).

Page 12, please replace paragraph [0048] with the following amended paragraph:

[0048] The injector 71 has a high-pressure connection 73. Highly pressurized fuel (not shown) is supplied to the injector 71 via the high-pressure connection 73. If an injection into the combustion chamber, not shown, of an internal combustion engine is to take place, a nozzle needle 75 lifts away from its seat, not shown, and unblocks injection orifices that are also not shown. A piezoelectric actuator 79 actuates a control valve 77, which controls the nozzle needle 75. Between the piezoelectric actuator 79 and the control valve 77, a hydraulic coupler 81 is provided, an enlargement of which is depicted on the right side of Fig. [[1]] **2**.

Page 15, please replace paragraph [0058] with the following amended paragraph:

[0058] When the blank 9 is rolled to form a hollow body 4 (see Fig. 4) and the ends of this hollow body 4 are acted on with a compressive force via an upper cover plate 5 (see Fig. 1) and a lower cover plate 6 (see Fig. 1), then the force F acting between the upper cover plate 5 and the edge 15 over the circumference of the hollow body 4 has the curve qualitatively depicted by the line 25 (see Fig. 5). The circumference angle [[j]] $\underline{\varphi}$ begins with 0° at the edge 13 and ends with 360° at the edge 11.

Please replace paragraph [0059] with the following amended paragraph:

[0059] It is clear that wherever a bridge piece 19 "supports" the edge 15, a large force F can be transmitted, as indicated by the maxima 27 of the line 25. The sole exception is where the edges 11 and 13 abut each other. The "cut" recess 7 there, with its parts 7′ and 7′′, weakens the structure of the blank 9 so that the force F transmitted between the upper cover plate 5 and the hollow body 4 is weaker at this point. This fact is indicated in Fig. 3 by the maxima 27 of significantly lower value for the force F at [[j]] $\underline{\varphi}$ = 0° and at [[j]] $\underline{\varphi}$ = 360°.

Please replace paragraph [0060] with the following amended paragraph:

[0060] The edge 17 behaves similarly. As is clear from Fig. 3, in the immediate vicinity of the edge 17 at [[j]] $\underline{\varphi}$ = 0° and 360°, there is a cut recess comprised of the parts 7′ and 7′′ whereas in the immediate vicinity of the edge 15 at [[j]] $\underline{\varphi}$ = 0° and 360°, there is a split bridge piece 19 with the halves 19′ and 19′′. This results in a somewhat different force curve over the circumference of the edge 17.

Page 16, please replace paragraph [0061] with the following amended paragraph:

[0061] As is clear from the lower F/[[j]] $\underline{\varphi}$ graph in Fig. 3, there are four maxima 27 and two local maxima 29 in the vicinity of the edges 11 and 13 at the angles [[j]] $\underline{\varphi}$ = 30° and 330° that are significantly lower than the maxima 27.

Page 17, please replace paragraph [0065] with the following amended paragraph:

[0065] According to the present invention, in the blank 9, the recesses 7a and 7b adjacent to the edges 11 and 13 have a geometry that has been altered in comparison to the rest of the

recesses 7, not all of which have been provided with reference lines. The different geometries of the recesses 7, 7a, and 7b will be explained in greater detail below in conjunction with the detail A from the blank 9. In this exemplary embodiment, the recesses 7a and 7b have the same geometry. As is clear from Fig. 4, the recesses 7, 7a, and 7b are "bone-shaped." Each recess 7, 7a, 7b is comprised of a middle ~~piece~~ **portion** 37 and two head ~~pieces~~ **portions** 39 adjoining this. The reference numerals 37 and 39 have been attached by way of example to only a single recess 7. The head ~~pieces~~ **portion** 39 can be quantitatively described by a first radius R_1 while the middle ~~pieces~~ **portion** 37 can be quantitatively described by a second radius R_2. Another important geometric value of the recesses 7, 7a, and 7b is the length L. It has turned out to be advantageous here if the first radius of the recesses 7a and 7b is smaller by a factor of 0.867 than the first radius of the recesses 7. It has also turned out to be advantageous if the second radius R_2 (7a, 7b) of the recesses 7a and 7b is greater by a factor of 1.317 than the second radius R_2 of the recesses 7 and if the length L of the recesses 7a and 7b is shorter by a factor of 0.984 than the length of the recesses 7.

Page 18, please replace paragraph [0067] with the following amended paragraph:

[0067] The second row contains four recesses 7 and one each of recesses 7a and 7b. The recesses 7a and 7b are disposed so that they are in the immediate vicinity of the edges 11 and 13. Since the recesses 7a and 7b are smaller than the recesses 7, the hollow body 4 is reinforced at a circumference angle [[j]] **φ** of 30° and a circumference angle [[j]] **φ** of 330°, namely in those places where the recesses 7a and 7b influence the spring rate of the hollow body 4. This reinforcing in the region of the circumference angles of [[j]] **φ** = 30° and 330°

compensates for the weakening of the hollow body 4 by the joint 31 disposed between the edges 11 and 13 (see Fig. 4). The result of this measure is clearly shown in the F/[[j]] **φ** graph shown above the blank 9. In comparison to Fig. 3, in which there is a significant drop in the transmittable force in the vicinity of the circumference angles [[j]] **φ** = 30° and 330°, in the F/[[j]] **φ** graph in Fig. 5, there are six maxima 27, that all represent the same amount. This means that a hollow body 4 manufactured from the blank 9 according to Fig. 5 has a uniform spring rate over the circumference of its ends 15 and 17 so that the spring force transmitted by the hollow body 4 to an upper or lower cover plate and/or a shoulder 91 or 93 acts exclusively in the axial direction and does not exert any lateral forces or bending moments on the components on which the spring force of the hollow body 4 acts. A blank 9 according to Fig. 5 can therefore attain the object according to the present invention.

Page 20, please replace paragraph [0073] with the following amended paragraph:

[0073] However, reference is made to the lower detail B in Fig. 8c. In it, the first radius R_1 of the recesses 7a and 7b at the end oriented toward the edges 11 and 13 (not shown) is composed of three arc segments 43. In the middle, there is a first arc segment 43 with a radius of 0.6 mm, which is adjoined at both ends by two second arc segments 45 with a radius of 0.25 mm. The recesses 7a and 7b whose geometry is described in conjunction with Fig. 8c are exemplary embodiments for recesses in which the first radii of the head ~~pieces~~ **portions** of a recess 7a or 7b adjacent to the joint differ from each other ~~as described in conjunction with claim 7~~.

Please replace paragraph [0074] with the following amended paragraph:

[0074] Fig. 9 is an F/[[j]] $\underline{\varphi}$ graph of a hollow body 4 manufactured from a blank according to Fig. 8, in various load states. Three lines that correspond to three different forces F1, F2, and F1 depict the load states. It is clear from Fig. 9 that the spring rate of the hollow body 4 is constant over the circumference in a wide range of load states.

Please replace paragraph [0076] with the following amended paragraph:

[0076] The blank 9 is not perforated in the region of the edges 15 and 17 that correspond to a second end and a first end of the hollow body 4. This reinforces the hollow body [[7]] $\underline{4}$ in the region of its first end 17 and in the region of its second end 15, which reduces the value of the maxima 27 (see Fig. 3, Fig. 5, and Fig. 9).

Page 21, please replace paragraph [0077] with the following amended paragraph:

[0077] A second essential measure for improving the hollow body 4 is comprised in individually adapting the width a of the bridge pieces 19 to the loads that occur. The bridge piece 19.1 in the first row of recesses 7 that are disposed in the immediate vicinity of the edges 11 and 13 is thus wider than a bridge piece 19.2 that is disposed in the blank, farther away from the edges 11 and 13. In the exemplary embodiment shown, the width a_1 of the bridge piece 19.1 adjacent to the edges 11 and 13 is 1.2 mm, whereas the other bridge pieces 19.2 have a width a_2 of only 0.75 mm. Depending of the dimensioning of the bridge piece widths a_1 and a_2, there can even be an overcompensation for the weakening of the hollow body 4 due to the presence of the joint 31. This effect is demonstrated in Fig. 11, which is an F/[[j]] $\underline{\varphi}$ graph. If the bridge piece width a_1 is selected as shown in Fig. 10b, then all six

maxima 27 are of the same amount. This design is indicated in Fig. 10b by the "bridge piece width a_1 = 1.2". If the bridge piece width in the immediate vicinity of the edges 11 and 13 is further increased, then the spring rate of the hollow body at the circumference angles [[j]] **φ** = 30° and [[j]] **φ** = 330° is greater than in the angle regions between them. This results in a superelevation of the curve in the vicinity of the circumference angles 30° and 330°, which is indicated in Fig. 11 by the line "bridge piece width 3."

Please replace paragraph [0078] with the following amended paragraph:

[0078] Fig. 12 shows another exemplary embodiment of a blank 9 according to the present invention in which the bridge piece widths have been individually determined as a function of the load situation. The blank 9 is symmetrical in relation to a symmetry axis 47 so that the dimensioning of the detail A, which depicts a quadrant of the blank 9, represents by reflection the overall dimensions of the entire blank 9 (not shown). The reference numerals 7, R_1, R_2, L, 19, 21, and others have been omitted from Fig. 12 for the sake of clarity. It should also be noted with regard to Fig. 12 that the same bridge piece widths are provided in the first row of recesses and in the 15th row of recesses. In addition, the bridge piece widths are the same in the second, fourth, sixth, eight, tenth, and fourteenth row of recesses. The bridge piece widths are also the same in the third, fifth, seventh, ninth, eleventh, **twelfth,** and thirteenth rows of recesses.

Page 22, please replace paragraph [0080] with the following amended paragraph:

[0080] As a matter of course, each of the characteristics described in the specification, **illustrated in** the drawings, or **recited in** the claims can be essential to the present invention either individually or in combination with other characteristics.

Please add the following new paragraph after paragraph [0080]:

[0081] The foregoing relates to preferred exemplary embodiments of the invention, it being understood that other variants and embodiments thereof are possible within the spirit and scope of the invention, the latter being defined by the appended claims.